# Ultraviolet Radiation

**E. C. Weatherhead**

Ultraviolet radiation (UV) is only a small portion of the radiation we receive from the sun, but has a large impact on biological activity. UV radiation has become a topic of increasing concern because of ozone depletion observed since the 1970s.

## Physical Definition

Ultraviolet Radiation is defined as all radiation between 100 and 400 nm. Although there are other sources of UV radiation, such as welding arcs and some lamps, most UV reaches the biosphere from the sun. The UV portion is less than 10% of the total energy output from the sun. Most of the UV radiation is then absorbed or scattered back to space by the earth's atmosphere, resulting in very little UV radiation reaching the earth's surface.

All radiation from the sun travels in the form of electromagnetic waves. The types of solar radiation are characterized in terms of wavelength, which is the distance between two points of identical phase in successive cycles of the wave. Wavelengths just shorter than those of light at the violet end of the visible spectrum are referred to as ultraviolet radiation.

Ultraviolet radiation can be divided into three basic categories:

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| UVA | 320-400 nm | the majority of the UV spectrum and most prevalent in reaching the biosphere; affected little by ozone |
| UVB | 280-320 nm | reaches the biosphere; highly affected by ozone |
| UVC | 100-280 nm | little reaches the biosphere; primarily scattered and absorbed by atmospheric oxygen, nitrogen and ozone. |

Some communities consider 315 nm to be a more appropriate dividing point between UVA and UVB radiation categories; the absolute division between UVA and UVB has not yet been determined.

## UV Levels

Since the early 1990s, scientists have placed a large emphasis on monitoring UV radiation. The interest in UV is based on a myriad of reasons, including detecting changes in the amount of radiation reaching the earth; increasing public awareness of UV; assessing UV's biological effects; and establishing a basic UV climatology. UV is measured at over 100 sites around the world, primarily in North America and Europe. Surface UV can be measured by ground-based instruments such as a spectrophotometer or estimated by satellite instruments like the Total Ozone Mapping Spectrometer (TOMS). Ground-based instruments are best at measuring the UV reaching the surface at a particular location, but require accurate calibrations and standardization of observations. Satellite instruments provide global coverage but the observations must be corrected for clouds and other atmospheric variables.

The ongoing measurements from both surface and satellite show how a number of factors, including ozone, cloud, and ground cover, can affect UV levels. Generally, as stratospheric ozone amounts decrease, more UV radiation is able to penetrate to the earth's surface. The relationship between ozone and surface-level UV is shown in Figure 1 for several locations worldwide. In addition to ozone concentration, other important factors governing UV levels are sun angle and cloud amount. Differences in sun angle can strongly affect the amount of UV radiation received directly. Frederick and Snell (1990) show that clouds can reduce the amount of UV reaching the ground by as much as 90% on a given day.

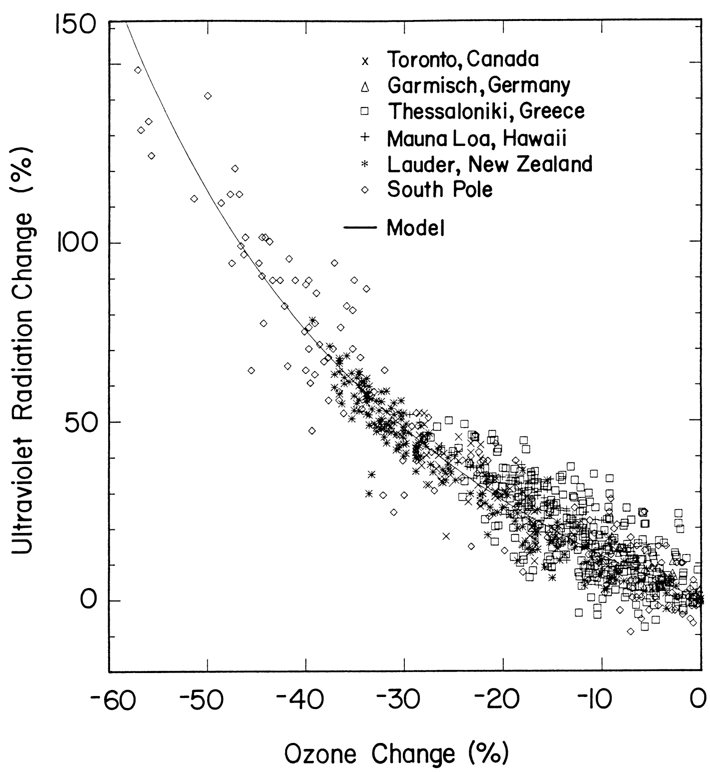


Figure 1. Increases in biologically effective UV radiation due to ozone decreases. From the World Meteorological Organization Scientific Assessment of Ozone Depletion, 1998.

UV levels can also be affected by surface reflectivity, altitude, and pollutants, including both aerosols and trace gases. Studies of these quantities are important for several reasons. Understanding the processes affecting UV allows scientists to estimate UV levels in times and places when measurements are unavailable. The improved understanding also helps scientists estimate how a changing environment will affect UV levels and vice versa.

**UV Effects**

UV has a variety of effects on plants, animals, and materials in the biosphere, most of them detrimental. UV is known to affect materials, particularly plastics and easily broken polymers. UV drives both stratospheric and tropospheric chemistry. However, most of UV effects studied involve the impacts of UV on biology. These effects range from human health impacts to impacts on single cell organisms. Underlying many of these studies is the fact that each UV photon has more energy than most other photons encountered in nature. As shown in Figure 2, the biological response to UV radiation is most significant at shorter wavelengths. Additionally, UV wavelengths, particularly those associated with UVB, are able to efficiently break DNA bonds. While UV, particularly UVA, can assist in repairing DNA damage, the primary effect of UV appears to be damaging to both DNA and individual cells.

Figure 2. Biological response as a function of wavelength. The shorter wavelength UV radiation is the most important in causing biological damage. From Weatherhead and Webb (1997).

The effects of UV on individual species and ecosystems have been studied both in the laboratory and in field experiments. UV is known to have primarily deleterious effects on individual species, including phytoplankton, zooplankton, amphibians, terrestrial plants and fish. However, the effects of UV on ecosystems can be unexpected or confounding. Studies by Bjorn et al. have shown that the growth rates of some shrubs can be hurt or helped by additional UV depending on available water supplies (AMAP, 1998). Other studies have shown that UV can change ecosystems by favoring UV resistant species. The effects can be strong and measurable, but are not always intuitive or obvious without careful study.

The most well-known effects of UV on people include sunburn and snow blindness (photo-keratitis). UV has also been linked to skin cancer, immune suppression, and cataract formation as well as a number of dermatological and ocular problems. These effects have been observed either in controlled laboratory experiments or from epidemiological studies. These studies help to explain, for instance, the differences in skin cancer incidence by latitude.

**Recent Changes**

Decreases in ozone over the past three decades have been well documented and their causes now fairly well understood. While we know from daily data that decreases in ozone lead to increases in UV radiation, long-term records of ultraviolet radiation are more difficult to interpret. Scotto et al. (1988) showed that UV data from 1974-1985 indicated a decrease in UV when an increase was expected. Weatherhead et al. (1997) later re-examined the long-term records and showed that they were inconclusive.

Blumthaler and Ambach (1990) showed an increase of almost 1% per year in spring Alpine UV data. Using three years of data, Kerr and McElroy (1993) showed an increase in UV that agreed with the decrease in ozone observed during the same time period.

A question remains about UV levels in centuries past. No consistent UV monitoring existed before the 1900s on which to base a definitive answer. However, our current understanding of the effects of UV allows us some insights when examining biological records. While our current estimates are very rough, our best estimate is that UV was not much different during the past millenium than it was prior to the 1970s, when anthropogenic ozone destruction began.

Future UV levels are likely to be dictated by both anthropogenic and natural variations. Human activity with respect to ozone depleting substances and with respect to climate change will likely determine long-term changes in UV levels. The slow recovery predicted for the ozone layer and the uncertainty associated with enforcing international legislation to control ozone depleting substances imply that UV levels are likely to be elevated above natural levels for many decades to come.

Whether elevated UV levels are a critical environmental threat or only part of the many changes affecting our environment is an important question. The answer depends on the total impact of UV to the environment. Our current understanding of the full impact of elevated UV levels does not allow a clear answer to this question.

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